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Radiotelemetry of Echidnas and Platypus

Lyn A. Beard and Gordon C. Grigg
Physiological Ecology Laboratory, Department of Zoology & Entomology,
The University of Queensland, Brisbane, Australia 4072

ABSTRACT

We used implanted transmitters to track echidnas and record body temperatures year round. The resultant discovery of hibernation in these non-placental mammals (but not in their close relatives, Platypus), sometimes in quite benign climates, poses questions about the origin of the ability to hibernate and the origin of endothermy itself. To help answer some of these, we developed a configuration for implantable transmitters to monitor heart rate in the field as an index of metabolic rate.

INTRODUCTION

Australia is home to two out of the three surviving monotremes in the world, the short-beaked echidna, *Tachyglossus aculeatus* and the platypus, *Ornithorhyncus anatinus*. The third, the long-beaked echidna, *Zaglossus bruijnii*, is found in New Guinea to Australia's north. Monotremes are the only egg-laying mammals and have traditionally been considered among the most primitive of mammals. They are also poor homeotherms. However, Australia's echidna is successful enough to be the only native mammal to enjoy an Australia-wide distribution, from hot, dry deserts to wet tropics to cold alpine regions. It was the occurrence of echidnas in the latter, even atop Australia's highest peak, Mt Kosciusko (2230m) in winter, which first prompted our study. If these poorly homeothermic mammals existed in Australia's coldest region, were they living and breeding there by choice or were they merely lost?

When we began our study 13 years ago, a good deal of basic biological knowledge about this species had been gathered from specimens brought into captivity, serendipitous observations in the field and dissection of dead specimens (see Griffiths 1968, 1978). However, there was little known about their behaviour in the wild. Although reasonably common, echidnas are extremely cryptic, rarely seen even by avid bushwalkers and there is no way to attract them into a trap. Thus radiotelemetry offers the only real opportunity to follow and study these animals in the wild and there had been only a few short-term studies of this type (Augee *et al*. 1975, Griffiths *et al*. 1988), by the time we began ours.

METHODS AND RESULTS

Echidnas

We needed to be able to track our study animals and, as we were interested in the homeothermic capabilities of echidnas, particularly as they related to a cold climate, we required implantable temperature sensitive radio transmitters as well. Early attempts to attach external tracking transmitters to these animals for extended periods failed. Echidnas have no neck for a collar and external glueing was short-lived due to their habit of pushing through tight holes and vegetation.

So we learnt, by default to rely on the internal temperature-sensitive transmitter for both tracking and body temperature measurements.

We used a 2-stage transmitter (originally Austec Enterprises, Canada; more recently Sirtrack Ltd, New Zealand) with internal loop antenna around an AA lithium battery operating on the 150-151 mHz band. To economize on battery life, we ordered our transmitters with a slower pulse rate than commonly supplied; about 1500-1600 ms pulse interval at 30^o C. This gave the original transmitters a working life of more than one year with the lithium batteries available at the time and 2 ½ to 3 years, depending on temperature, with the current transmitters and 2400 mAh batteries now available.

Each transmitter was coated in an elvax mixture (see Grigg and Beard, this volume) to render it biologically inert. The smooth, ovoid package weighed approximately 33g (most of our experimental animals were between 2 and 4 kg with the largest over 6kg) and was allowed to float freely in the body cavity. Transmitters were implanted under halothane anaesthesia (induced in a flow-through box at 5% and maintained on a mask at 2-4%), in the peritoneal cavity via a mid-ventral incision along the linea alba. The incision was closed with an internal layer of dissolving sutures (vicryl, Ethicon) followed by an external layer of vertical mattress sutures in silk. This type of suture was necessary to maintain the integrity of the healing wound, as echidnas otherwise could split their sutures by flexing very strong abdominal muscles when curling up into a defensive posture or digging. Silk was chosen because it is easy to tie, less prone to unravel than a monofilament type, and "wears out" more easily in the field. We released the animals as soon as possible following the operation, believing that the stress associated with holding a wild animal in captivity is a hindrance to successful recovery. All procedures were carried out under as sterile conditions as possible, following a protocol approved by the University's animal experimentation and ethics committee. Animals healed well. There was no infection and transmitters were able to be recovered cleanly and replaced in subsequent operations using the same incision site.

Animals were tracked using a Telonics TR2 receiver+scanner and RA 2A hand held "H" antenna. As they are low to the ground and are often down burrows, our minimum range was 200 to 300m routinely in lightly timbered, undulating country, often up to 600m, and over 1 km with good line of sight. As echidnas have a home range averaging 0.5 km^2, this was usually sufficient. The record was 11km from across a lake to an echidna in a log on a hill on the opposite shore. We also used the sometimes-disadvantageous side-effect of uneven signal radiation from the internal loop antenna to deduce movement when the animal was out of sight, for example in a nursery burrow.

There were no great surprises at first when the animals were released in late summer. Body temperatures were quite heterothermic but with a consistent daily pattern (Figure 1 and Grigg et al 1989,1992) ranging from 32 to 33 ^oC when active to 27 or 28 ^oC during overnight inactivity. However, within two months, the power of telemetry was demonstrated when one of the echidnas was found under a rock pile with a transmitter pulse rate indicative of a body temperature of 9^oC! The next day, however, it was found to have warmed up and moved. So we had evidence that echidnas can become torpid for short periods, which had been suspected from previous anecdotal reports.

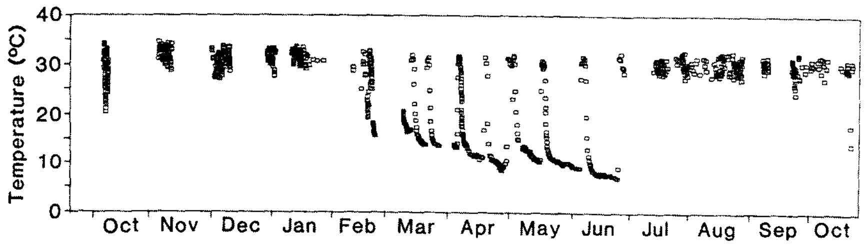

Figure 1. Annual pattern of body temperature in a male echidna from Australia's alpine region.

A bigger surprise was revealed after several more months tracking through winter, when a classic pattern of true hibernation emerged, virtually indistinguishable from that of advanced eutherian mammals such as the arctic ground squirrel (Figure 1). Note the drop in body temperatures to almost ambient for extended periods, interrupted by periodic arousals to normal operating temperatures, as seen in northern hemisphere hibernators.

Platypus

This discovery stimulated us to wonder about those other monotremes, platypus. The following winter we applied the same techniques to a population of these animals in the Thredbo River. This is one of the coldest rivers inhabited by platypus, being fed by meltwater from snow and with a mean winter minimum temperature of 2.8 ^{o}C. Platypus are smaller than echidnas (approximately 600g-1100g), so the transmitters were fitted with ½ AA batteries and the AA-sized loop antenna was convoluted to fit the smaller package. Even with the resultant range attenuation, we could still get 100-400m from an animal in the water, quite – adequate for our purposes. We never found any evidence of hibernation in these beasts (Grigg et al. 1992) but telemetry again revealed, within a couple of days, interesting behaviours such as burrow sharing by males, previously unknown to Tom Grant, a platypus expert of some 20 years standing, whom we had invited to join us in the study.

Automatic Monitoring

The body temperature data for both echidnas and platypus were originally gathered manually, often camping within range of the animal to get hourly readings. However, this was time-consuming and tedious so we invented a simple automatic recording system. This consisted of a specially constructed electronic timer which switched on and off a tape recorder and radio receiver at user-determined intervals, with the antenna mounted in a tree to maximise the receiving range (see Grigg et al. 1990, Grigg and Beard, this volume). The resultant tape needed to be read later in the lab, measuring the intervals between recorded pulses for each reading to determine temperature, but the system compressed continuous monitoring over days or even weeks into the length of a cassette tape.

Dataloggers

These days, more complete body temperature profiles may be gained by the implantation of a temperature sensitive datalogger (eg Tidbit, Onset Corp, USA). The disadvantage of this equipment is that it is dependant on recovering the logger from the animal to download the data. If the animal gets lost or the logger fails before the end of the observation period (we usually leave our animals in the field for over a year) all data is lost. But this is not the case if the data is gathered progressively, by monitoring the radio transmitter.

We have now recorded year-round body temperature patterns for echidnas from several different areas and are discovering that echidnas hibernate (albeit facultatively) even in the mild climate of south east Queensland, where frosts are comparatively uncommon and it almost never snows. Conventional thinking on hibernation holds that it is a means of overwintering in extreme conditions such as cold and/or lack of food. Neither of these scenarios holds true for echidnas. In the alpine areas, echidnas enter hibernation as early as February (late summer) when their food source of ants and termites is still plentiful and there is definitely no snow cover. Moreover, they emerge from hibernation at the coldest time of the year (July-August) to breed. Echidnas resident in south east Queensland enjoy even more benign conditions. The challenge then, is to try to explain WHY echidnas hibernate. Perhaps trying to understand this could hold the key to understanding the origin of the ability to hibernate, or even the origin of endothermy itself.

Heart Rate Telemetry

To this end, we were interested to learn more about how hibernation might figure in an echidna's yearly energy budget. Pilot experiments by an honours student indicated that heart rate could be used as a reasonably satisfactory predictor of oxygen consumption and, hence, metabolic rate. For this we needed to be able to monitor heart rate under natural conditions in the field throughout the whole hibernation season.

We had attempted heart rate monitoring quite early on in the study using heart rate transmitters (Stuart Enterprises) configured, like the temperature transmitters, as smooth, ovoid and wax-coated bodies with the electrodes as stainless steel buttons embedded in the wax at each end. These transmitters were triggered by the QRS complex of the wave of electrical depolarisation associated with each heart beat and, like the temperature transmitters, were allowed to float freely in the body cavity.

Unfortunately, at least half of the time the transmitters were frustratingly silent or returned equally frustrating scrambled signals from random firing or triggering by muscular activity. We assumed this to be because of the poor coupling of the electrodes to the animal and inappropriate sensitivity. Nonetheless we obtained some good data, including some from two animals in hibernation which registered heart rates as low as 3-4 per minute at body temperatures around 10^{o}C. We also obtained some tantalizing support for the current controversial theory that metabolic rate (as measured by heart rate in this case) is depressed during hibernation further than it would be simply as a consequence of the Q_{10} effect of lower body temperature (Grigg and Beard, 1996).

Recently, with Louise Kuchel, we sought to improve the methodology, this time using transmitters developed by Sirtrack Ltd (NZ). Like the earlier transmitters, these new heart rate transmitters are also triggered by the difference in the electrical potential between two electrodes detected as the wave of depolarisation associated with each heart beat spreads out through the body. This is more economical on battery power than continuous wave models which require the transmitter to be 'awake' at all times and therefore allows for potentially long term monitoring (up to a year). There are two important considerations. One is to have the electrodes from the transmitter far enough apart to detect the potential difference. The other is to have the electrodes well enough 'coupled' to the animal to pick up what can be quite a weak signal in smallish animals.

At first we tried implanting the transmitter body subcutaneously on the ventral flank, with two longish electrode leads terminating in wire loop electrodes tunnelled under the skin to attachment points on the ventral surface. The best placement for the electrodes was found, using a Maclab physiograph (AD Instruments), to be with one near the posterior end of the sternum and the other on the lateral abdomen just anterior to the hind leg. However, the electrode leads broke, the electrodes themselves broke off, and the transmitter body migrated under the influence of gravity to a position uncomfortable for the echidna.

We decided, therefore, to try again with an intraperitoneal implant and, due to the echidna's extremely strong body musculature and habit of curling into a tight ball when disturbed, to leave it unattached to any body parts. We are now having good success with a stainless steel 10mm diameter button electrode on the body of the transmitter and a 10 x .6mm "bullet" electrode held distant at the end of a 6cm sturdy but flexible whip made of stainless steel fishing trace inside silastic tubing.

The new transmitters also have increased sensitivity, maximum between 0.10 and 0.15 mv, and a small, user-adjustable sensitivity screw. Measurements with the Maclab, and experience, have shown that a sensitivity setting of about 0.3 mv is suitable for this transmitter configuration in echidnas. However, random firing, often triggered by muscular activity, can still be a problem, as can double firing if the transmitter picks up the "T' wave of the EKG as well as the targeted "QRS" complex.

To minimise these artifacts, the transmitter has a delay circuit so that, once triggered, it will not fire again within a factory-set time interval after the first stimulus. For echidnas, this latent period is set at 300ms which is just a bit shorter than the time between heart beats at the maximum heart rate observed for these animals in the wild. In addition, use of a square, flat "Keeper" brand battery gives the whole transmitter a flattened body shape which encourages it to stay in the best orientation for picking up heart rate, with the button electrode facing towards the skin to minimise interference from muscular activity.

Our study animals now routinely carry a temperature-sensitive transmitter, heart rate transmitter and temperature datalogger, all in the peritoneal cavity. With this combination, we can achieve almost a full year's monitoring of heart rate and up to three years' body temperature data both in real time and electronically archived. The combined weight of the hardware is approximately 85g which is less than 0.5% of the body mass of the 2.5-4.5 kg animals in our study. As far as can be ascertained, there seems to be no interference with the animals' normal behaviour. Telemetered individuals breed successfully and exhibit spectacular pre-hibernation weight gains.

The Future

As to the future, we would like to see further miniaturisations in loggers, especially for implantation, increased battery energy densities and, hopefully, commercial realisation of heartrate loggers, all of which would greatly facilitate studies of this type. Also, we would like to see the development of implantable, longlived loggers or archival tags which can be downloaded and reprogrammed remotely at will (by radio?) while within the animal.

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